UNCLASSIFIED

AD NUMBER

AD872085

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 1 Jun 1970. Other requests shall be referred to U.S. Army Test and Evaluation Cmd, Aberdeen Proving Ground, MD 21005. REL TO: Australia, Canada, and United Kingdom.

AUTHORITY

USATEC ltr, 14 Dec 1970

THIS PAGE IS UNCLASSIFIED

AD-872085

U. S. ARMY AND EVALUATION COMMAND
COMMON SERVICE TEST PROCEDURE

ROUND-TO-ROUND DISPERSION

1. OBJECTIVE

The objective of this Materiel Test Procedure (MTP) is to provide guidance for conducting direct-sight firing of artillery class weapons against vertical targets to determine dispersion characteristics and hit probability.

2. BACKGROUND

Final acceptability of a weapon is largely governed by its ability to deliver effective fire rapidly and accurately on a target. Small dispersion is a major factor in accomplishing this goal. Extraneous variables in the test facilities which might affect the impact pattern should be eliminated or reduced to the maximum extent possible during this test.

Good hit probability is achieved when the dispersion is small and the mean of the points of impact (center of impact) is near the point of aim.

Data obtained from this test are used to evaluate design changes and to justify production, further development, or termination of a project.

3. REQUIRED EQUIPMENT

a. Binoculars and Spotting Scopes
b. Appropriate Firing Ranges
c. Ambulance with Medical Aid Personnel and Equipment
d. Targets, 20 foot square
e. Meteorological Equipment, as required for:

    1) Windspeed and direction
    2) Ambient temperature
    3) Relative humidity

f. Boresighting Devices, as required
g. Qualified Gunner's M1A1 Quadrant
h. Pullover Gage
i. Forms for Recording Data
j. Tape Measure
k. Gridded Target
l. Appropriate Standard Ammunition, as required
m. Storage Material - Dunnage, etc.

4. REFERENCES

A. Applicable Range Regulations and Standing Operating Procedures.
B. Frankford Arsenal Report R-1380A, Fire Control Studies Tank Gunnery Accuracy Evaluation, February 1958 or later revision.

20020813335

C. Pertinent Technical Publications.
D. Qualitative Materiel Requirement (QMR), Small Development Requirement (SDR) or other appropriate document.
E. USAMCR 385-12, Verification of Safety of Materiel from Development through Testing, Production, and Supply to Disposition.
F. USAMCR 385-24, Range Safety.
G. USATECOM Regulation 385-6, Verification of Safety of Materiel During Testing.
H. MTP 2-3-500, Preoperational Inspection and Physical Characteristics.
I. MTP 3-3-500, Preoperational Inspection and Physical Characteristics (Armament and Individual Weapons).
J. MTP 3-3-503, Boresight and Zero.
K. MTP 10-3-501, Operator Training and Familiarization.

5. SCOPE

5.1 SUMMARY

This MTP describes the following:

a. Preparation for Test - Procedures for training and familiarization of personnel, inspection of materiel, preparation of range site, positioning of the weapon mount and boresighting and zeroing of the weapon system.
b. Dispersion Firing - A measurement of the dispersion of pertinent types of ammunition provided for the weapon system, both primary and secondary, at various stages of gun barrel life under as controlled conditions as practical at service test installations.

5.2 LIMITATIONS

The contents of this document are primarily concerned with direct fire, large caliber vehicle-mounted weapon systems. However, by proper selection of procedures and minor alterations in methodology, it could be made usable for other weapon systems.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Safety

The test officer shall ensure that a Safety Release has been received from HQ, USATECOM in accordance with reference 4G and that it is understood prior to commencing testing.

6.1.2 Personnel

a. Ensure the availability of service personnel, representative of those that will operate the test item in the field, who have been trained in

1) Pertinent technical publications for the test items
2) Applicable range regulations and standing operating procedures
3) Objectives of the test
4) Pertinent data required
5) Method of obtaining observations
6) Method of recording data
7) Safety hazards

b. Record the following for all test personnel:

1) Name, rank or grade
2) Military Occupational Specialty (MOS)
3) Training time in MOS
4) Experience in MOS

6.1.3 Inspection

Subject weapon system and vehicle on which it is mounted to the applicable inspections described in MTP 2-3-500 and MTP 3-3-500 recording all pertinent data on the test vehicle, test weapon system and the number of rounds previously fired through the gun and gun barrel.

6.1.4 Ammunition

The test officer shall ensure the availability of sufficient standard ammunition for each weapon to be tested and the following shall be recorded for each type of ammunition:

a. Number of rounds received
b. Lot number of rounds received

6.1.5 Pretest Operations

a. Erect the following:

1) Twenty foot (6.1 meter) square vertical targets at specified surveyed intervals over the required range of engagement, or if there is not a requirement, at 800, 1,200, 1,600 and 2,000 meters.

NOTE: Data is normally computed on the basis of a 7-½ foot (2.3 x 2.3 meter) square target, but for the purposes of this test all points of impact for rounds fired should be measured.

2) A boresight and zeroing target, as described in MTP 3-3-503 at the required range for the weapon system, or if none is specified, at 1,200 meters.

NOTE: The direction from the firing point(s) to the boresight and zeroing targets and the test targets should be as

nearly the same as possible and angle of site must be near zero. All targets must have a distinct aiming cross.

3) A gridded target at a convenient range as described in MTP 3-3-503.

NOTE: This target is for checking the alinement of sights throughout subsequent firing exercises.

b. Provisions shall be made for storing ammunition at the firing point(s).

NOTE: Ammunition should be stored on dunnage and covered or protected to ensure that powder temperature remains approximately the same for each round of any one group fired.

c. Place available meteorological equipment near the firing site.

d. Position the firing vehicle at the firing point on level ground and set brakes. Measure vehicle cant and pitch and angle of site with a M1A1 quadrant and record data.

e. Perform all required prefiring checks.

f. Boresight each sighting system as the range specified or selected for zeroing as described in MTP 3-3-503 and record the equipment used and the setting on each boresight knob or sight upon completion of boresighting.

g. Zero the weapon system as described in MTP 3-3-503 using the appropriate ballistic mechanisms and firing the primary round developed for the weapon, and record the following:

NOTE: 1. "Zeroing" implies firing the weapon and adjusting the optical sights to the target center of impact (CI) until the CI is on or close to the gunner's point of aim.
2. Direction of lay must be standardized for both azimuth and elevation in order to minimize the effects of backlash.
3. Firing should be done with the gun in the forward position with respect to the vehicle.

1) New boresight knob or sight setting.

NOTE: The difference in the position (mils) between the "boresighted" and "zeroed" knob settings is a measure of the bias errors due to wind, drift, cant, muzzle velocity, etc. Minimize environmental effects by avoiding firing where rapid changes in ambient conditions are apparent.

2) Range and azimuth to the target.
3) Fire control equipment used.
4) Ammunition used by type and lot number and the number of rounds fired.
5) Distance of CI of final zeroing group from aiming point.
6) Ambient temperature, relative humidity, windspeed and direction.

h. Aim weapon system on the gridded target and mark or record point of alinement for each optical sight and the gun barrel.

6.2 TEST CONDUCT

6.2.1 Dispersion Firing - Primary Fire Control System

NOTE: 1. Initial dispersion firing should be done near the beginning of the service test and as soon as practical after zeroing to minimize the effects of ground weather changes.
2. If there is an appreciable delay between zeroing and dispersion firing a warm-up round should be fired.
3. Firing over prolonged time intervals or during periods where rapid changes in ground weather conditions are apparent will be avoided.

a. Insert proper data for the primary round into the computer or ballistic drive, when applicable.

b. Load the round and lay the sight precisely on the intermediate (zeroing) range target and fire two 10-round shot groups using the following guidelines:

NOTE: A parallax shield (a disc containing a small circular aperture) may be placed over the eyepiece of the primary sighting device.

1) Always make the final horizontal and vertical lays in the same direction to eliminate or reduce the effects of backlash.
2) All rounds for a given shot group will be of the same lot number.
3) Range input data shall not be changed during the firing of a shot group.
4) Armament shall be relaid prior to firing each round.
5) The elevation of the weapon should be measured with an M1A1 gunner's quadrant, using the pads provided on the breech of the gun, before each round is fired.
6) Rounds should be fired at 1 to 3 minute intervals, when possible, to avoid the buildup of heat in the barrel and breech and to minimize effects of weather change.
7) Alinement of fire control optical instruments should be rechecked on the gridded target after each group is fired or any time there is an appreciable change in elevation of the weapon as measured with the M1A1 gunner's quadrant or impact of projectiles on the target.

c. Measure the distance from the point of aim to the center of each projectile impact hole and record the following:

1) For each round fired:

a) Date and time of firing.
b) Horizontal and vertical distance of impact from point of aim.
c) Elevation of weapon above line of sight as measured with a M1A1 gunner's quadrant.

2) For each group fired:

a) Gunner's name.
b) For each test system (weapon/fire control/vehicle) used:

(1) Serial number of gun and fire control components.
(2) Vehicle nomenclature, test miles operated and pitch or cant during firing.
(3) Angle of site.

c) Whether parallax shield was used and size of aperture, when applicable.
d) Distance and azimuth to target and range setting used.
e) Type and lot number of ammunition used.
f) Ambient temperature, relative-humidity and windspeed and direction.

3) Loss of boresight, if any (measured on gridded target).
4) Pullover gage readings, when applicable.

NOTE: Periodically pullover gage measurements of the gun should be made to determine the amount of wear caused by firing the various type rounds and the effects such wear may have on dispersion characteristics.

d. Repeat steps outlined in steps a, b, and c above for each of the other selected ranges.

e. Repeat steps outlined in steps a, b, c and d above for each other type of ammunition provided.

f. Repeat steps outlined in paragraphs a, b, c, d, and e above at approximately half way through the service test and again near the completion of the test.

6.2.2 Dispersion Firing - Secondary Fire Control System

Determine the dispersion of the secondary fire control system, at the different ranges of paragraph 6.2.1, by firing 3-round groups concurrently with the firing of the primary fire control system and recording the data of paragraph 6.2.1.c.

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Personnel

Record the following for all test personnel:

a. Name
b. Rank or grade
c. MOS
d. Training time in MOS in months
e. Experience in MOS in months

6.3.1.2 Inspection

Record the following:

a. Vehicle inspection data collected as described in the applicable sections of MTP 2-3-500.
b. Weapon system inspection data for each weapon, collected as described in the applicable sections of MTP 3-3-500.
c. Number of rounds fired; for each weapon, when applicable:

1) Through the gun
2) Through the gun barrel

6.3.1.3 Ammunition

Record the following for each type ammunition recorded:

a. Type of ammunition
b. Lot number
c. Number of rounds recorded

6.3.1.4 Pretesting Operations

Record the following:

a. For the firing site:

1) Pitch and cant of test vehicle in degrees
2) Angle of site in degrees
3) Angle, in degrees, from firing point to:

a) Boresight and zeroing target
b) Test targets

b. For boresighting:

1) Equipment used
2) Setting on each boresight knob or sight

c. For zeroing:

1) Setting on each boresight knob or sight
2) Range to target in meters

3) Azimuth to target in mils
4) Fire control equipment used
5) For ammunition used:

   a) Type
   b) Lot number
   c) Number of rounds used

6) Distance of CI of final zeroing group from the aiming point
7) Ambient temperature in °F.
8) Relative humidity in %
9) Windspeed and direction in mph and degrees, respectively
10) Point of alinement of the following on the gridded target:

   a) Each optical sight
   b) Gun barrel

6.3.2 Test Conduct

Record the following for each fire control system:

a. Fire control system being tested (primary, secondary)
b. For each round fired:

   1) Date and time in minutes, hour, day, month and year
   2) Horizontal distance of impact from point of aim in inches
   3) Vertical distance of impact from point of aim in inches
   4) Elevation of weapon above line of sight in mils

c. For each group fired:

   1) Gunner's name.
   2) Serial number of:

      a) Gun used
      b) Fire control component(s) used

   3) Angle of site.
   4) For test vehicle:

      a) Nomenclature
      b) Test miles operated
      c) Pitch in degrees
      d) Cant in degrees

   5) Whether parallax shield was used and size of aperture, when applicable.
   6) Distance to target in meters.
   7) Range setting used.
   8) Azimuth to target in degrees.
   9) Type ammunition used.

10) Ammunition lot number.
11) Ambient temperature in °F.
12) Relative humidity in %.
13) Windspeed in mph and direction in degrees.
14) Loss of boresight, if any.
15) For pullover gage measurements:

a) Number of rounds fired by weapon
b) Measurements obtained

6.4 DATA REDUCTION

6.4.1 Dispersion

a. A standard (unbiased) deviation in mils shall be computed for each 10-round group of each type of ammunition fired.

NOTE: Reference 4B gives the dispersion requirement for tank main armament as: A standard (unbiased) deviation not exceeding 0.19 mils in deflection and elevation at all ranges up to and including 2,000 yards; a standard (unbiased) deviation up to and including 0.22 mils is acceptable. Deviations from this criterion may be allowed for projectiles having exceptional terminal effectiveness. (Requirements contained in a QMR, SDR, or other official document of a later date will take precedence over those in reference 4B).

b. Computation of the sample unbiased standard deviation in inches is shown by this example:

1) A shot group was fired at 1,500 meters. The group consisted of 10 rounds, which upon measurement were found to be distributed as follows with respect to the aiming point (locations below or left of aiming point are considered minus):

	Distance from Aiming Point (Inches)	
Round No.	Horizontal (X)	Vertical (Y)
1	-5	-1
2	-3	-17
3	-5	21
4	-8	-18
5	16	-15
6	-7	-13
7	18	-48
8	-14	-8
9	-19	-26
10	-6	5

2) Center of Impact. To find the center of impact (CI) all horizontal and all vertical measurements were added algebraically (subtracting minus values, adding plus values). These sums are -33 inches horizontal and -120 inches vertical. Divided by 10 (the number of rounds in the shot group)

the values become -3.3 and -12.0 inches respectively; these numbers are the location of the CI ($\bar{X}$ and $\bar{Y}$) measured in inches horizontally and vertically from the aiming point.

3) Standard Deviations. To calculate the biased horizontal and vertical standard deviations, the location of each round from the CI was determined. This was accomplished by subtracting algebraically the CI value from the individual round location as originally measured. (Algebraically this operation is $X-\bar{X}$ and $Y-\bar{Y}$). These new values were each squared and summed for horizontal and vertical values separately. These sums were divided by 10 (the number of rounds in the shot group) and the square root of the result was extracted. The results are the sample (biased) standard deviations. The following numerical work demonstrates this procedure as it applies to the example.

Number	$X-\bar{X}$	$(X-\bar{X})^2$	$Y-\bar{Y}$	$(Y-\bar{Y})^2$
1	-1.7	2.89	11.0	121
2	0.3	0.09	-5.0	25
3	-1.7	2.89	33.0	1,089
4	-4.7	22.09	-6.0	36
5	19.3	372.49	-3.0	9
6	-3.7	13.69	01.0	1
7	21.3	453.69	-36.0	1,296
8	-10.7	114.49	4.0	16
9	-15.7	246.49	-14.0	196
10	-2.7	7.29	17.0	289
TOTALS		1,236.10		3,078
DIVIDED BY 10:		123.61		307.8
SQUARE ROOT OR SAMPLE (BIASED) STANDARD DEVIATION:		11.12 inches		17.54 inches

NOTE: The sample (biased) standard deviation was multiplied by the multiplier for a 10-round group in Figure 1 to get the standard (unbiased) deviation.

MULTIPLIED BY 1.084	12.05 inches	19.01 inches

The CI and standard deviation were converted from inches to mils by use of the mil formula as follows:

$$\text{Mils} = \frac{1000 \times W}{R}$$, where W and R are the linear measure and range expressed in the same units

$$\text{Mils} = \frac{1000 \times W}{39.37 \times R}$$, where W is in inches and R is in meters

a) Then for CI:

$$\frac{-3.3 \times 1000}{39.37 \times 1500} = 0.056 \text{ mils left}$$

$$\frac{-12.0 \times 1000}{39.37 \times 1500} = 0.203 \text{ mils down}$$

b) Standard (Unbiased) Deviation:

$$\frac{12.05 \times 1000}{39.37 \times 1500} = 0.204 \text{ mils horizontal}$$

$$\frac{19.01 \times 1000}{39.37 \times 1500} = 0.322 \text{ mils vertical}$$

Number of Rounds in Group	Multipliers or Factors for Standard Deviation
2	1.772
3	1.382
4	1.253
5	1.189
6	1.151
7	1.126
8	1.108
9	1.094
10	1.084
11	1.075
12	1.068
13	1.063
14	1.058
15	1.054

Figure 1. Factors to be Used in Calculating the Population Standard Deviation from the Sample Standard Deviation (reference 4B).

6.4.2 Confidence Interval

A 90% upper confidence limit on the horizontal and vertical true standard deviation will be computed for each type of ammunition fired.

6.4.2.1 Formula

The formula for computing the 90% upper confidence limit is:

a. Group the firing into "k" number of groups; each group composed of "h" firings.

b. Calculate the sample variance (square of the standard deviation) for each group:

$$(s_i^2 \quad i = 1, 2 \ldots k).$$

c. Average the sample variances.

$$S^2 = \sum_{i=1}^{k} \frac{s_i^2}{k}$$

d. Determine the overall sample standard deviation by finding the square root of the average sample variance.

$$S = \sqrt{\sum_{i=1}^{k} \frac{s_i^2}{k}}$$

e. Since the assumption has been made that the underlying distribution for the population is normal, then the chi-square distribution can be used to determine the upper confidence limit on the true standard deviation.

$$(x^2_{n-1} = \frac{n-1}{\sigma^2} S^2)$$

The number of degrees of freedom is determined by multiplying the number of firings in the groups, minus one, times the number of groups.

$$(n-1 = (h-1).(k)$$

f. Then the 90% probability for the upper confidence limit to contain the true standard deviation is

$$P\left(0 \leq \sigma \leq S\sqrt{\frac{n-1}{x^2_{.90,\ n-1}}}\right) = .90$$

where: σ is the true standard deviation;
S is the overall sample standard deviation;
(n-1) is the number of degrees of freedom;
$x^2_{.90,\ n-1}$ is the value of the chi-square distribution at 90% and (n-1) degrees of freedom. (Value is obtained from chi-square tables.)

g. Hence, the inequality $\sigma \leq S \sqrt{\frac{n-1}{x^2_{.90,\ n-1}}}$ will yield the desired upper confidence limit.

6.4.2.2 Example

a. The formula in paragraph 6.4.2.1 is illustrated in the following example to determine the horizontal upper confidence limit:

1) Given eighty firings of a type of ammunition, group them into eight different groups of 10 firings each, i.e., h = 10, k = 8.

2) The sample variances (square of the standard deviation for the eight groups) are:

$s_1^2 = (.084)^2 = .00706$ $\quad s_5^2 = (.176)^2 = .03097$

$s_2^2 = (.126)^2 = .01587$ $\quad s_6^2 = (.088)^2 = .00774$

$s_3^2 = (.172)^2 = .02958$ $\quad s_7^2 = (.213)^2 = .04537$

$s_4^2 = (.107)^2 = .01145$ $\quad s_8^2 = (.219)^2 = .04796$

3) The average of the sample variances is:

$$S^2 = \sum_{i=1}^{8} \frac{s_i^2}{k} = \frac{.1960}{8} = .0245.$$

4) The overall sample standard deviation is:

$$S = \sqrt{\sum_{i=1}^{8} \frac{s_i^2}{k}} = \sqrt{.0245} = .15653.$$

5) The number of degrees of freedom is:

$(n-1) = (h-1).(k) = (10-1).(8) = 72.$

The value of chi-square for 90% and 72 degrees of freedom is 57.1. (Obtained from chi-square tables.)

6) Then the 90% probability for the upper confidence limit to contain the true standard deviation is:

$$P\left(0 \leq \sigma \leq S\sqrt{\frac{72}{57.1}}\right) = .90.$$

For S = .15653 the inequality is

$$\sigma \leq 0.15653 \sqrt{\frac{72}{57.1}} = 0.15653\ (1.123) = 0.1758.$$

7) Hence, the 90% upper confidence limit for the horizontal standard deviation is 0.1758 mils.

b. Repeat the process outlined in paragraph a above to determine the vertical upper confidence limit.

6.4.3 Hit Probability

Using the standard (unbiased) deviation computed as shown in paragraph 6.4.1 above in conjunction with the Hit Probability Nomograph (Appendix A) determine the hit probability as explained on the Nomograph.

6.4.4 Effects of Barrel Wear

Compare the shot groups fired at various stages of barrel wear to determine the effects such wear may have on dispersion and hit probability.

GLOSSARY

1. Cant: Sidewise tilting of a gun, measured in mils left or right.

2. Center of Impact: Mean point of a group of shots, measured by as the average distance of all rounds from the point of aim.

3. Pitch: Lengthwise tilting of a vehicle, usually forward.

4. Standard Deviation: The best measure of dispersion from the standpoint of statistical efficiency.

5. Biased Standard Deviation: The standard deviation of a single group of rounds where an appreciable bias exists because of the small sample.

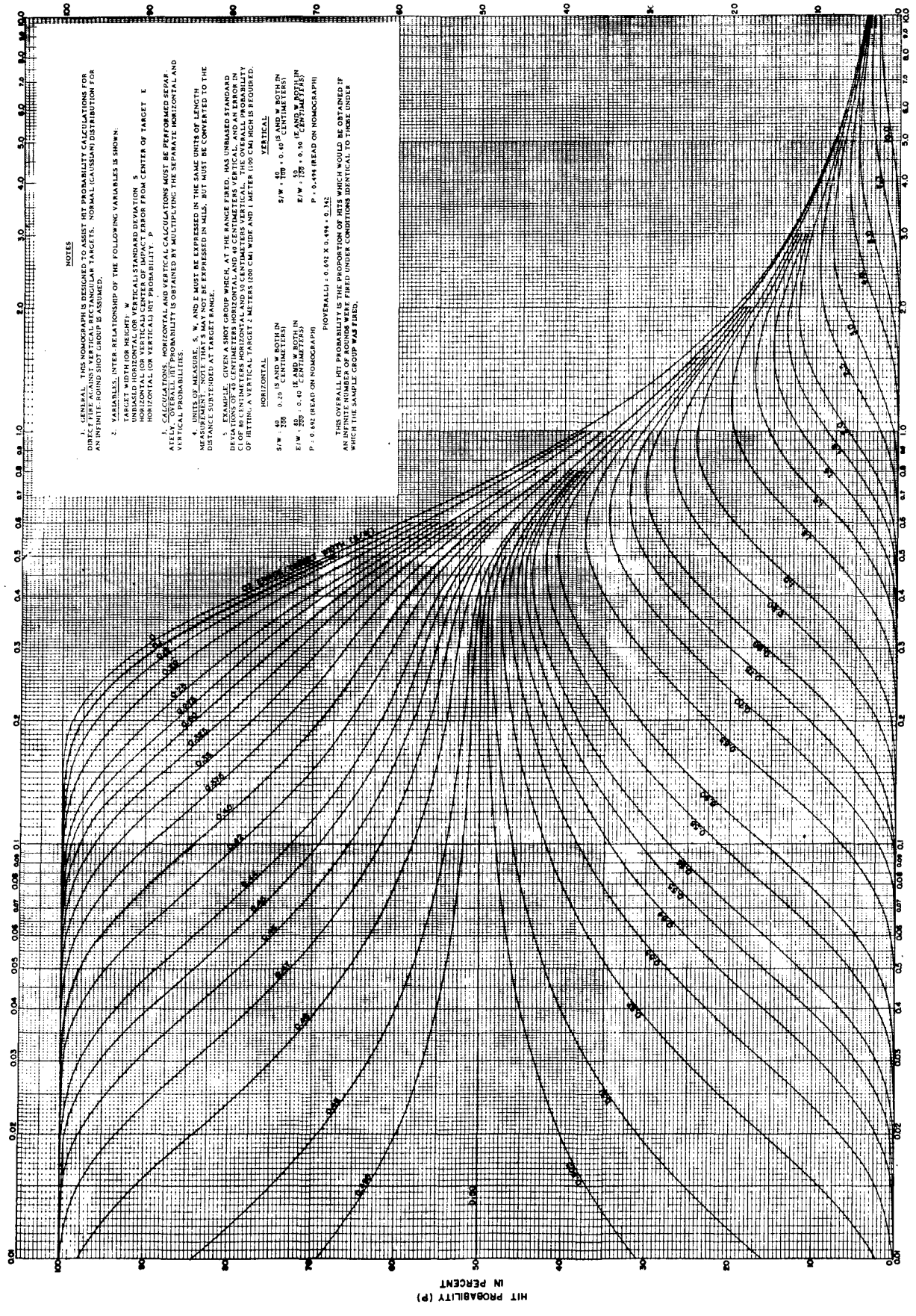
   Bias: A systematic or constant error. (In the absence of bias the average of a large number of observations will be close to the true value. The population average of an unbiased set of measurements will equal the true value of the property measured.)

6. True or Unbiased Standard Deviation: The standard deviation of a small sample that has been converted to an estimate of the population (infinite sample size). This is usually referred to as just "standard deviation".

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

Hit Probability Nomograph



THIS PAGE INTENTIONALLY LEFT BLANK

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
US Army Test and Evaluation Command (USATECOM)
Aberdeen Proving Ground, Maryland 21005

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP
---

3. REPORT TITLE
U. S. Army Test and Evaluation Command Materiel Test Procedure 3-3-512, Common Service Test Procedure, - "Round-to-Round Dispersion."

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Final

5. AUTHOR(S) *(First name, middle initial, last name)*
---

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1 June 1970	20	11

8a. CONTRACT OR GRANT NO.
DA-18-001-AMC-1045(R)

b. PROJECT NO.
AMCR 310-6

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
MTP 3-3-512

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
---AD 872085

10. DISTRIBUTION STATEMENT
This document is subject to special export controls and each transmittal to foreign governments or foreign nationals,-WITH THE EXCEPTION OF AUSTRALIA, CANADA, AND UNITED KINGDOM,-may be made only with prior approval of HQ,USATECOM.

11. SUPPLEMENTARY NOTES
---

12. SPONSORING MILITARY ACTIVITY
Headquarters
US Army Test and Evaluation Command
Aberdeen Proving Ground, Maryland 21005

13. ABSTRACT

This Army Service Test Procedure describes test methods and techniques for evaluating the dispersion characteristics and hit probability of artillery class weapons. The procedure is intended for application to test of large-caliber, direct-fire vehicle-mounted weapons. The evaluation is related to criteria expressed in applicable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC), or other appropriate design requirements and specifications.

DD FORM 1 NOV 65 1473 (PAGE 1)
S/N 0101-807-6811

UNCLASSIFIED
Security Classification

A-31408

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Army Service Test						
Artillery Dispersion Characteristics and Hit Probability						
Combat Vehicle-Mounted Weapons Systems (Direct-firing Artillery Class)						
Test Procedures						
Test Methods and Techniques						

DD FORM 1 NOV 65 1473 (BACK)
S/N 0101-807-6821

UNCLASSIFIED
Security Classification

A-31409